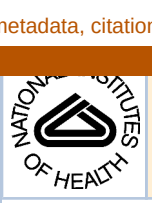

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Diagnostic Ionizing Radiation Exposure in a Population-based Sample of Children with Inflammatory Bowel Diseases

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Abstract

Background and Aims—The degree of diagnostic radiation exposure in children with inflammatory bowel diseases (IBD) is largely unknown. Here we describe this exposure in a population-based sample of children with IBD and determine characteristics associated with moderate radiation exposure.

Methods—We ascertained radiological study use, demographic characteristics, IBD medication use, and the requirement for hospitalization, emergency department (ED) encounter, or inpatient GI surgery among children with IBD within a large insurance claims database. Characteristics associated with moderate radiation exposure (at least one computed tomography (CT) or three fluoroscopies over two years) were determined using logistic regression models.

Results—We identified 965 children with Crohn's Disease (CD) and 628 with Ulcerative Colitis (UC). Over 24 months, 34% of CD subjects and 23% of UC subjects were exposed to moderate diagnostic radiation [odds ratio (OR) 1.71, 95% confidence interval (CI), 1.36–2.14]. CT accounted for 28% and 25% of all studies in CD and UC subjects, respectively. For CD subjects, moderate

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Specific author contributions:

Dr. Palmer participated in the conception and design of the study, data preparation, data analysis, and manuscript preparation. She was involved in final document editing and has approved the final draft submitted.

Dr. Herfarth participated in the conception and design of the study. He was involved in final document editing and has approved the final draft submitted.

Ms. Porter provided data abstraction and dataset preparation services. She was involved in final document editing and has approved the final draft submitted.

Dr. Fordham participated in the conception and design of the study. She was involved in final document editing and has approved the final draft submitted.

Dr. Sandler participated in the conception and design of the study. He was involved in final document editing and has approved the final draft submitted.

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radiation exposure was associated with hospitalization (OR 4.89, 95% CI 3.37–7.09), surgery (OR 2.93, 95% CI 1.59–5.39), ED encounter (OR 2.65, 1.93–3.64 95% CI), oral steroids (OR 2.25, 95% CI 1.50–3.38), and budesonide (OR 1.80, 95% CI 1.10–3.06); an inverse association was seen with immunomodulator use (OR 0.67, 95% CI 0.47–0.97). Except for oral steroids and immunomodulators, similar relationships were seen in UC.

Conclusion—A substantial proportion of children with IBD are exposed to moderate amounts of radiation as a result of diagnostic testing. This high utilization may impart long-term risk given the chronic nature of the disease.

INTRODUCTION

Inflammatory bowel diseases (IBD), including ulcerative colitis (UC) and Crohn's disease (CD), are chronic, autoimmune diseases of the intestines that can begin in childhood. Both follow a fluctuating, life-long course with multiple acute episodes or "flares" interspersed between periods of quiescence. Advances in the treatment of IBD have led to novel therapeutics that may alter the course of the disease. However, individuals with IBD have an increased-risk of developing various malignancies, both from the disease itself and from therapeutics used to treat the disease.(1–5)

Diagnostic imaging, including the use of radiological tests such as fluoroscopy and computed tomography (CT), has become an increasingly important component of the evaluation and management of IBD. However, diagnostic ionizing radiation represents an additional IBD-related exposure with carcinogenic potential.(6,7) Of particular concern is CT, which can impart radiation doses that are over 100 times that of a conventional x-ray film.(8) Ionizing radiation increases the risk of several types of malignancies, including hematologic and solid-organ cancers. Observational studies of atomic bomb and nuclear disaster survivors as well as radiation industry workers have demonstrated an increased-risk of death from malignancy with even moderate exposures.(9–12) Low-level, protracted radiation exposures (such as those associated with medical imaging) have also been associated with malignancy.(9,13–16)

The pediatric population is particularly vulnerable to the effects of ionizing radiation.(11,17) Compared to adults, children have more biologically active tissue with less intervening space between susceptible organs. In addition, they have a lifetime in which to develop radiation-induced complications. Consequently, it has been estimated that the ionizing radiation imparted in one computed tomography before the age of 15 incurs a 1 in 1500 excess risk of cancer mortality.(18)

Despite these risks of radiation, the use of CT has increased in the general United States (US) population by approximately twenty-fold over the last twenty-five years.(8) Even more concerning is that between 6% and 11% of CT scans in the US are performed in children, (19) the subgroup of the population with the highest risk. Several recent studies have documented that the utilization of CT in adult IBD patients has far outpaced CT utilization in the general population. One tertiary IBD referral center demonstrated a 380% increase in the use of CT over a fifteen year period,(7) and another population-based investigation reported an 870% increase in the use of CT enterography.(20) However, the utilization of diagnostic ionizing radiation in US children with IBD remains poorly characterized.

Given the exponential increase in diagnostic radiation exposure by adult IBD patients, and the particular concern for malignancy risk in pediatric patients, we sought to describe the utilization of diagnostic ionizing radiation in a population-based sample of children with UC and CD. We also examined the patient characteristics associated with moderate dose imaging exposure.

METHODS

Study Design and Data Source

In this cross-sectional study, we analyzed the medical, surgical, and pharmaceutical insurance claims contained in the PharMetrics© Patient-Centric Database (IMS Health, Watertown, MA) for the period January 1, 2003 through December 31, 2004. Prior studies have used this longitudinal, patient-level database to examine the prevalence and costs of IBD.(21) At the time of this study, the PharMetrics database included claims from 87 health plans in 33 states and was reported to be representative of the national commercially-insured population on a variety of demographic measures, including geographic region, age, gender, and health plan type.(22)

Patient Selection

All children age 18 and under at the time of identification with continuous health plan enrollment between January 1, 2003 and December 1, 2004 were eligible for inclusion in this analysis. We identified cases of UC and CD using a previously described administrative claims ascertainment algorithm.(21) This definition included patients with at least three health care contacts, on different days, associated with an International Classification of Diseases, 9th Revision, (ICD-9) Clinical Modification diagnosis code for UC (556.xx) or CD (555.xx), or patients with at least one claim for UC or CD and at least one pharmacy claim for any of the following medications: mesalamine, osalazine, balsalazide, sulfasalazine, 6-mercaptopurine, azathioprine, infliximab, adalimumab, and enteral budesonide. For patients who had claims for both UC and CD, disease assignment was made according to the majority of the last 9 claims.

Exposure Ascertainment

To determine outcomes and exposures of interest, we classified each claim as inpatient, outpatient, or pharmaceutical according to Current Procedural Terminology (CPT), Healthcare Common Procedure Coding System (HCPCS), or National Drug Codes (NDC). We identified several exposures of interest within our study population, including age, gender, geographical region (Northeast, South, Midwest, and West), the requirement for hospitalization with a primary diagnosis of UC (556.xx) or CD (555.xx), emergency department (ED) encounters that did not result in hospitalization, and the requirement for inpatient gastrointestinal (GI) surgery (one or more claims during a period of any-cause hospitalization that contained a procedure code for a gastrointestinal operation, excluding surgery of the liver, biliary tract, and pancreas).

We also examined patient exposure to IBD-specific medical therapy, including oral or rectal salicylates (mesalamine, osalazine, balsalazide, or sulfasalazine), immunomodulators (6-mercaptopurine, azathioprine, or methotrexate), anti-TNF alpha agents (infliximab or adalimumab), oral steroids, and enteral-release budesonide. Subjects were considered exposed to medical therapy if they had at least 2 pharmacy claims for the medications over the time of the study.

Outcome Description

All occurrences of 23 different types of diagnostic imaging studies were identified via CPT codes, including CT of the abdomen and/or pelvis; CT angiogram (CTA) of the abdomen, mesentery, or aorta; CT enterography; abdominal X-ray, fistulogram or sinogram; upper GI series; upper GI series with small-bowel follow-through; small-bowel follow-through without upper GI series; contrast enema; endoscopic retrograde cholangiopancreatography (ERCP), cholangiography or cholecystography; small bowel enteroclysis, as well as selected non-GI

studies. A complete list of CPT classification codes is included in the supplemental material (See Supplementary Table 1 online). Due to the fact that that multiple claim lines are often submitted for a single encounter (facility fees, technical services, professional services, etc), we counted all claims for the same type of imaging test occurring on the same day as a single study. When both a CT of the abdomen and a CT of the pelvis occurred on the same day, they were counted as a single abdomino-pelvic CT.

Moderate dose radiation imaging was defined as at least one CT or three fluoroscopic procedures during the two-year observation period. We based this definition upon data from the atomic bomb survivor cohort indicating that the ionizing radiation dose imparted by one abdominal CT prior to the age of 15 carries a 1 in 1500 risk of death from malignancy, with risk falling logarithmically into one's third decade of life.(18) Also, published estimates of fluoroscopic and CT effective doses indicate that, on average, fluoroscopic procedures impart lower doses of ionizing radiation than CT scans.(23–28) CT scans impart one-hundred to one-hundred fifty times the dose of one conventional X-ray or bone mineral density exam; therefore, X-rays and bone mineral density exams were not included in the definition of moderate dose radiation imaging.(20,29)

Statistical Analysis

Standard univariate statistics were performed, including calculations of means, medians, proportions, ranges and interquartile ranges. The one continuous variable, age, was examined in its simple continuous form as well as categorical forms in order to determine the most valid and precise coding structure. Bivariate statistics (Pearson's chi-square, Wilcoxon rank-sum, or t-tests based on variable type) were used to assess for statistical associations between the receipt of moderate radiation imaging and the exposures of interest.

Multivariable logistic regression models estimating prevalence odds ratios were performed separately within the UC and CD samples. Methotrexate, azathioprine, and 6-mercaptopurine were analyzed as "immunomodulators", and adalimumab and infliximab were analyzed as "anti-TNF alpha agents". Adalimumab, infliximab, and budesonide were used rarely to treat UC at the time of the study and were excluded from the UC model. Each exposure was considered of potential interest; therefore, all potential risk factors were retained in the final model. Stata statistical software (Stata Ver. 10.0, College Station, Texas) was used for all statistical analyses. The study protocol was granted exemption from review by the Institutional Review Board at the University of North Carolina at Chapel Hill on September 9, 2008, because it involved the use of existing, de-identified data.

RESULTS

Sample Characteristics

We identified 1593 children with IBD (628 UC and 965 CD). The mean age was 14 years, with a standard deviation of 3 years [Table 1]. Forty-five percent of the sample was female, and patients were relatively evenly divided among the four regional areas (34.2% Northeast, 16.8% West, 21.4% South, and 27.6% Midwest). The only statistical differences between the UC and CD groups were in the use of IBD specific medications. More children with CD were exposed to immunomodulators (43% versus 26%, $p<0.05$), anti-TNF alpha agents (15.4% versus 3.2%, $p<0.05$) and budesonide (9% versus 4%, $p<0.05$). Conversely, more children with UC were exposed to rectal salicylates (26% versus 6%, $p<0.05$). Approximately one-quarter of the sample was hospitalized at least once over the two-year period, 37% had at least one emergency department encounter that did not result in hospitalization, and 8% underwent an inpatient GI surgery.

Diagnostic Radiation Exposure

Over the two year period, 23% of children with UC and 34% of children with CD were exposed to moderate radiation imaging [odds ratio (OR) 1.71, 95% confidence interval (CI), 1.36–2.1]. Forty-nine percent of UC subjects and 33% of CD subjects received no imaging studies. There was a median of 1 CT, 1 fluoroscopy, and 2 x-rays in the group who were exposed to any imaging. When we examined the distribution by study type, x-ray exams (plain film exams of chest, abdomen, or pelvis, and bone mineral density exams) were the most commonly ordered study (60% of imaging in UC; 48% in CD) [Figure 1]. CT comprised 25% of all studies ordered for children with UC and 28% of all studies ordered for children with CD. Fluoroscopic procedures were the least-commonly performed study (16% of imaging in UC; 23% in CD). Six percent of CD subjects and 5% of UC subjects underwent 3 or more CT scans, and 1.8% of CD subjects and 2.2% of UC subjects underwent 5 or more CT scans. Detailed utilization of all imaging studies over the two year period is shown in Table 2 and Table 3.

Factors associated with moderate radiation imaging

The results of multivariable regression modeling for children with CD demonstrate that IBD-related hospitalization (OR 4.89, 95% CI 3.37–7.09), inpatient GI surgery (OR 2.93, 95% CI 1.59–5.39), use of oral steroids (OR 2.25, 95% CI 1.50–3.38), ED encounter (OR 2.65, 1.93–3.64 95% CI), and use of enteral budesonide (OR 1.80, 95% CI 1.10–3.06) were positively associated with the receipt of moderate dose radiation imaging, and immunomodulators were negatively associated (OR 0.67, 95% CI 0.47–0.97)[Table 4]. When we stratified our results by oral steroid use (a marker of disease flare), we found the inverse association with immunomodulator use was only present in those patients who did not require steroids during the observation period (unexposed to steroids: OR 0.55, 95% CI 0.36–0.85; exposed to steroids 1.36, 95% CI 0.62–2.99). Similar point estimates were seen in subjects with UC, though the only statistically significant associations were IBD-related hospitalization (OR 3.04, 95%CI 1.84–5.03), surgery (OR 4.13, 95%CI 1.85–9.22), and ED encounter (OR 3.27, 95%CI 2.13–5.01) [Table 4].

Age, gender, use of anti-TNF agents and use of oral or rectal salicylates were not associated with diagnostic radiation exposure in UC or CD. Regional variation was modest [Table 4].

We repeated the analyses using a definition of moderate dose radiation exposure as at least one CT or two fluoroscopic studies over the two year period. This resulted in an additional 29 children with CD (2%) and 11 children with UC (2%) classified as receiving moderate dose radiation exposure. The addition of these patients did not change the effect estimates in our multivariable models.

Imaging performed in patients without obvious risk factors may represent "overuse"(30) of radiological testing, and thus unnecessary radiation exposure. Therefore, we sought to further characterize the use of radiological studies in patients without hospitalization, surgery, ED encounters, and oral steroid use. In this low risk group, 13% of children with CD and 7% of children with UC received moderate radiation exposure through diagnostic imaging.

DISCUSSION

This population-based analysis has demonstrated that approximately one-third of commercially insured US children with CD and one quarter with UC were exposed to at least moderate amounts of diagnostic ionizing radiation over a two-year time period. Indicators of severe disease are associated with increased imaging, including hospitalization, surgery, ED encounters, and use of steroids. The use of immunomodulators is negatively associated with

radiation exposure in children with CD, which may reflect the growing body of literature demonstrating that immunomodulators are effective in maintaining disease remission.(31,32)

The widespread use of CT and other imaging modalities in pediatric IBD patients is consistent with the emerging literature in this area. Newnham and colleagues were the first to highlight the use of diagnostic radiation exposure in IBD patients.(6) They reported the imaging history of 62 subjects with CD and 48 subjects with UC (mean age 39 years, range 16–84 years) at a single, tertiary-care IBD referral center in Australia. Using a definition of "high risk" exposure as a cumulative dose greater than 50 mSv, they estimated that 11% of their sample was exposed to high levels of diagnostic ionizing radiation. Factors associated with high-level exposure included a diagnosis of CD versus UC (OR for UC 0.33, 95% CI 0.05–2.01) and undergoing surgery (OR 3.01, 95% CI 0.67–13.5). These results were not significant overall, likely due the small sample size of the study.

Two additional studies have confirmed these findings and have demonstrated the increase in CT use over time. One tertiary referral center in Ireland reported an increase in use of CT by 380% from the period spanning 1992–1997 to the period spanning 2002 to 2007. Peloquin and colleagues performed a population-based analysis of diagnostic radiation exposure in IBD patients in Olmstead County, Minnesota,(20) and also demonstrated a large increase in CT utilization.

Our study extends this prior work in a number of meaningful ways. First, we focus solely on pediatric patients. This population, which has been largely neglected in prior studies, is actually the most vulnerable to the harmful effects of radiation exposure. We found that CT comprised a significant proportion of imaging tests performed in pediatric IBD patients, particularly in children with CD. This partly explains the high proportion of children exposed to moderate ionizing radiation over the 24 month observation period. In addition, CT was used more often in this pediatric cohort than has been seen in studies of adults (up to 28% in our pediatric population versus 12% to 16% in adults (6,7)). A cohort effect based on the years of study is unlikely to explain this finding as the two years of our analysis fell between the study periods of the adult reports. The higher utilization of CT (and exposure to radiation) observed in pediatric patients as compared to adult patients may related to the increased severity and extent of disease in children compared with adults, as suggested in a number of recent reports.(33, 34) Alternatively, increased imaging may be a function of time-from-diagnosis. Prior work from Longobardi et al has demonstrated that healthcare resource utilization is most intense in the 2 years following diagnosis.(35,36) Children are more likely than adults to be closer to their time of diagnosis and potentially more likely to undergo imaging. Also, providers may view diagnostic medical imaging as non-invasive and therefore choose radiation-based tests before other strategies involving more immediate risks from sedation, biopsies, etc.

Despite the growing public health concern over the expanding use of high-dose diagnostic radiation, awareness of the risks is low among medical providers and patients. In a 2004 study of abdominal CT imaging in a US emergency department, 97% of patients, 91% of emergency medicine physicians and 53% of radiologists did not believe that CT studies could increase the risk of malignancy.(37) Only 7% of patients remembered discussing radiation risks prior to the exam. Practitioners in Great Britain demonstrated a similarly poor knowledge of radiation risks.(38) This suggests that while concerns for malignancy are of paramount importance with regards to *therapeutic* decision making, they do not appear to be a high priority with regards to *diagnostic* decision making.

The data presented here indicate that a substantial proportion of children with IBD are exposed to potentially harmful amounts of ionizing radiation as a result of diagnostic testing. Therefore, as with therapeutic decisions, we advocate that the risks, benefits, and alternatives to

fluoroscopic and CT studies be carefully considered. Emerging diagnostic alternatives to these studies include ultrasound and newer MRI imaging modalities where available.(39,40) Furthermore, a "watch and wait" approach with serial abdominal exams may also be helpful in identifying the possibility of disease complications and informing the need for subsequent imaging studies when this is clinically appropriate. Finally, for instances where CT and/or fluoroscopic studies are indicated, radiological protocols which minimize radiation exposure to the lowest extent possible should be utilized.(17) Indeed, Berdon and Slovis summarized a series on radiation doses from pediatric CT by indicating that as much as 30% of the dose from pediatric CT could be unnecessary.(41) The radiation dose from CT is being addressed on a national level through a number of approaches including the Image Gently campaign.(42)

This analysis has a few potential limitations that should be noted. Misclassification of subjects is always of concern when administrative claims are used as the primary data source. Both under-ascertainment of true cases of IBD and misclassification of other diseases as IBD can bias the results of administrative analyses. By requiring multiple diagnosis codes for either CD or UC and including the use of IBD-specific medications in our case definition algorithm, we attempted to optimize the sensitivity and overall accuracy of our administrative definition. Bernstein et al have used a similar administrative definition, which was developed and validated against primary medical record data.(43) Misclassification and/or under-ascertainment of outcomes may also be questioned when administrative databases are used as the primary data source. We feel that this type of bias would have a minimal effect upon our results as prior works have demonstrated that administrative claims are reliable when studying procedures that are highly linked to reimbursement, such as diagnostic testing, and are comparable to data found in medical records.(44–46)

An additional limitation of this study is that the timing of the exposure in relation to the outcome cannot be determined in a cross sectional analysis. We believe this to be of little consequence in our study because the burden of ionizing radiation exposure remains substantial regardless of whether the imaging was performed before, during, or after the IBD diagnosis. Also, administrative data contain a paucity of clinical information, such as disease phenotype, extent, severity, and time from diagnosis. These characteristics may be important in identifying children who are more likely to be exposed to multiple diagnostic tests over the course of their disease. A final limitation to our study is that we did not have sufficient detail to determine whether each diagnostic procedure was medically necessary or informative. However, we did find that 13% of CD patients and 7% of UC patients with apparently mild disease (no oral steroid use, ED encounter, hospitalization, or surgery) were exposed to moderate diagnostic radiation over the time period of this study. It is possible that some of the imaging performed on these patients without obvious risk factors may have been avoidable. Indeed, the overuse of diagnostic testing including CT has been reported in the pediatric ED setting.(47) However, a negative imaging study can also prevent unnecessary therapeutic interventions or inpatient admissions.

Our study has several strengths that add to prior work in this area. This is the largest, population-based study of diagnostic radiation utilization in pediatric IBD subjects. The geographical diversity of the study population and the inclusion of patients insured by a number of different health plans of varying structure and size make these results broadly generalizable to the commercially insured population of the United States. In addition, the large sample size in this study allowed us to examine the use and drivers of diagnostic testing in pediatric UC and CD patients separately, an important step in delineating the reasons behind the increased radiation exposure in CD patients. An additional strength of our study is that by utilizing administrative claims, we were able to analyze all radiologic examinations performed on each patient regardless of the facility. Thus our study complements single center studies that only have

access to the examinations performed at one facility and cannot capture *total* exposure when imaging is performed outside of that center.

Over 2 years, a substantial proportion of children with IBD were exposed to ionizing radiation as a result of diagnostic testing. A lifetime of diagnostic testing will magnify the risk. Children with IBD may be seen in numerous care settings, and it is imperative that providers at all levels of care are aware of the potential carcinogenic effects of medical radiation. Providers must communicate with each other to coordinate a plan for the diagnosis and management of IBD in children that considers both the risks of *diagnostic and therapeutic* decisions, as well as the life-long nature of the disease. While the individual risk of diagnostic radiation exposure to any one child is small, and the risk-benefit ratio generally favors diagnostic testing, the increasingly large number of exposed children may create a public health concern in the future. It is imperative that providers work together to reduce the radiation dose in pediatric exams, reduce the amount of unnecessary diagnostic testing, and increase the use alternative imaging modalities and/or watchful waiting when appropriate in the management of childhood IBD.

1. WHAT IS CURRENT KNOWLEDGE

Adults with inflammatory bowel diseases (IBD) are increasingly exposed to diagnostic medical radiation

Less is known about medical radiation exposure in the community, especially in children

Ionizing radiation, including diagnostic medical radiation, may increase malignancy risk

Children are more vulnerable to the effects of ionizing radiation than adults

2. WHAT IS NEW HERE

In only 2 years, almost one-third of children with IBD were exposed to moderate diagnostic medical radiation

Computed Tomography was used more often than has been seen in studies of adults with IBD

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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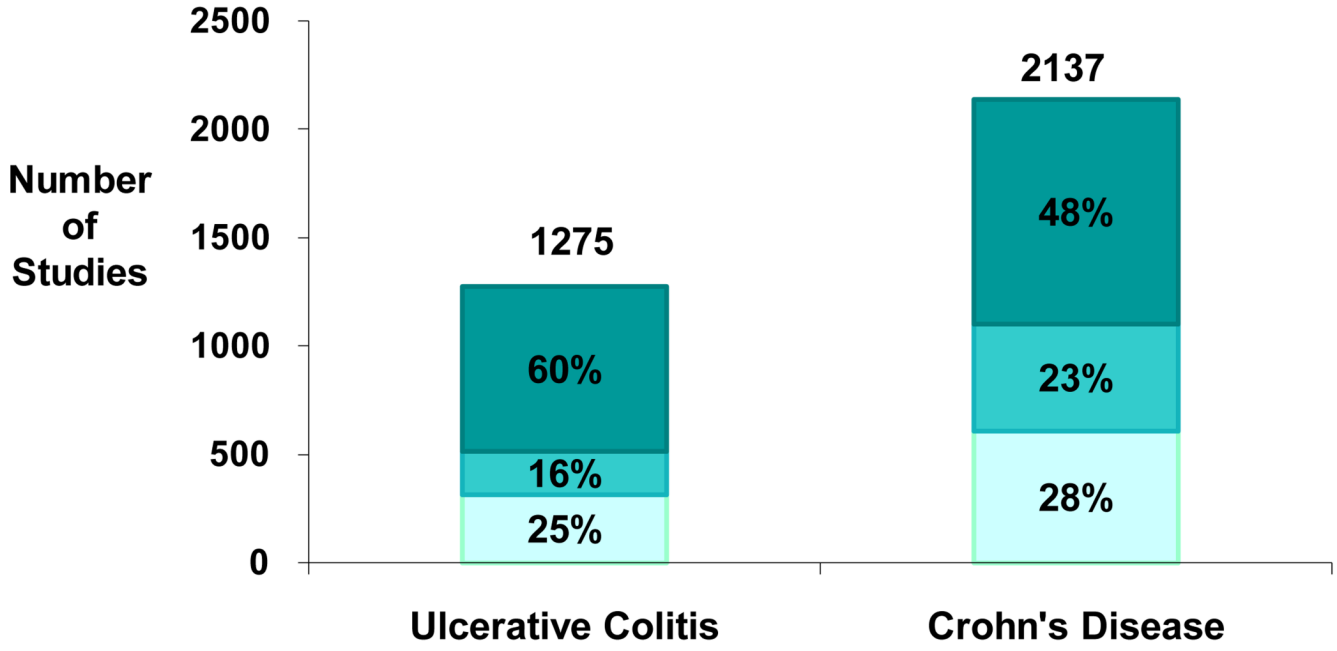

Figure 1.
Over the two year period, 1275 studies were performed in children with UC and 2137 were performed in children with CD. X-rays were the most commonly ordered study, comprising 60% and 48% of the studies performed in children with UC and CD, respectively. CT scans comprised 25% of the total imaging in children with UC and 28% in children with CD. Fluoroscopic exams were the least commonly ordered study (16% of studies in children with UC and 23% of studies in children with CD).

Table 1

Characteristics of a sample of children with inflammatory bowel disease, 2003–2004

	Ulcerative Colitis n(%)	Crohn's Disease n(%)	P-Value
Subjects	628(39.4)	965(60.6)	
Age (2–18) *	14 † 3.1 §	14 † 3.7 §	0.434 #
Sex (Female)	286(45.5)	423(43.8)	0.503
Medicaid	13(2)	34(3.5)	0.094
Region			
West	110(17.5)	158(16.4)	0.644
Northeast	210(33.4)	334(34.6)	
South	127(20.2)	214(22.2)	
Midwest	181(28.8)	259(26.8)	
Medication Therapy			
Oral Salicylates	357(56.9)	554(57.4)	0.825
Rectal Salicylates	164(26.11)	58(6.01)	<0.001
Immunomodulators **	166(26.4)	419(43.4)	<0.001
Methotrexate	4(0.6)	23(2.38)	0.008
Budesonide	23(3.7)	89(9.2)	<0.001
Adalimumab	2(0.2)	1(0.16)	0.829
Infliximab	20(3.2)	149(15.4)	<0.001
Oral Steroids	156(24.8)	205(21.2)	0.094
Hospitalized	151(24)	237(24.6)	0.815
Inpatient GI surgery	44(7)	85(8.8)	0.198
ED Encounter ‡	250(39.8)	344(35.6)	0.093

* Range,

† Mean,

§ Standard Deviation,

Wilcoxon Rank Sum,

** Includes Azathioprine and 6-Mercaptopurine

‡ ED = Emergency Department

Table 2

Type of Imaging Studies and Percent Receiving Studies, Crohn's Disease

Study Type	Percent (%) Receiving Study	Study Type	Percent (%) Receiving Study
CT[*] or CTA[†] of the Abdomen and/or Pelvis		**CT or CTA of the Head, Neck Extremities**	
No studies	69.6	No studies	95.1
1 study	17.7	1 study	3.9
≥2 (maximum 11)	12.6	≥2 (maximum 4)	0.9
UGI[‡], SBFT[§] or Contrast Enema		**CT or CTA of the Chest**	
No studies	62.0	No studies	97.9
1 study	30.9	1 study	2.0
≥2 (maximum 5)	7.2	≥2 (maximum 3)	0.1
Enteroclysis		**IVP[#] or VCUG[**]**	
No studies	98.8	No studies	99.9
1 study	1.0	1 study	0.1
≥2 (maximum 3)	0.2		
ERCP or Cholangiogram		**Pelvis X-ray**	
No studies	99.6	No studies	97.4
1 study	0.2	1 study	2.6
≥2 (maximum 3)	0.2		
Fistulogram or Sinogram		**Chest X-ray**	
No studies	99.5	No studies	74.1
1 study	0.4	1 study	16.1
≥2 (maximum 2)	0.1	≥2 (maximum 13)	9.8
Abdominal X-ray		**Bone Mineral Density**	
No studies	76.3	No studies	93.2
1 study	14.0	1 study	6.1
≥2 (maximum 33)	9.7	≥2 (maximum 4)	0.7

[*] CT = computed tomography

[†] CTA = computed tomography angiogram

[‡] UGI = upper GI series

[§] SBFT = small bowel follow through

[#] IVP = intravenous pyelogram

[**] VCUG = voiding cystourethogram

Table 3

Type of Imaging Studies and Percent Receiving Studies, Ulcerative Colitis

Study Type	Percent (%) Receiving Study	Study Type	Percent (%) Receiving Study
CT* or CTA† of the Abdomen and/or Pelvis		**CT or CTA of the Head, Neck Extremities**	
No studies	82.2	No studies	92.8
1 study	10.5	1 study	5.7
≥2 (maximum 13)	7.3	≥2 (maximum 4)	1.4
UGI‡, SBFT§ or Contrast Enema		**CT or CTA of the Chest**	
No studies	76.4	No studies	97.5
1 study	19.4	1 study	1.6
≥2 (maximum 6)	4.1	≥2 (maximum 7)	1.0
Enteroclysis		**IVP# or VCUG****	
No studies	99.8	No studies	99.8
1 study	0.2	1 study	0.2
ERCP or Cholangiogram		**Pelvis X-ray**	
No studies	99.0	No studies	97.3
1 study	0.8	1 study	2.2
≥2 (maximum 3)	0.2	≥2 (maximum 3)	0.5
Fistulogram or Sinogram		**Chest X-ray**	
No studies	99.8	No studies	79.1
1 study	0.2	1 study	13.0
		≥2 (maximum 23)	8.0
Abdominal X-ray		**Bone Mineral Density**	
No studies	78.3	No studies	95.5
1 study	9.2	1 study	3.7
≥2 (maximum 44)	12.4	≥2 (maximum 2)	0.8

*CT = computed tomography

†CTA = computed tomography angiogram

‡UGI = upper GI series

§SBFT = small bowel follow through

#IVP = intravenous pyelogram

**VCUG = voiding cystourethogram

Table 4

Factors associated with receipt of moderate dose imaging*

	Ulcerative Colitis		Crohn's Disease	
	OR†	(95% CI)‡	OR†	(95% CI)‡
Age >10	1.05	(0.57–1.93)	0.70	(0.42–1.19)
Gender (male)	0.74	(0.49–1.14)	0.80	(0.59–1.10)
Region (east)				
South	1.43	(0.84–2.86)	1.57	(1.02–2.40)
Midwest	1.59	(0.92–2.76)	1.07	(0.71–1.60)
West	1.16	(0.60–2.26)	1.37	(0.86–2.17)
Hospitalization	3.04	(1.84–5.03)	4.89	(3.37–7.09)
Surgery	4.13	(1.85–9.22)	2.93	(1.59–5.39)
ED§ Encounter	3.27	(2.13–5.01)	2.65	(1.93–3.64)
Oral Steroids	1.50	(0.86–2.60)	2.25	(1.50–3.38)
Budesonide	--		1.80	(1.10–3.06)
Immunomodulators#	0.86	(0.51–1.45)	0.67	(0.47–0.97)
Anti-TNF Agents**	--		0.97	(0.62–1.51)
Oral Salicylates	1.00	(0.62–1.62)	0.81	(0.58–1.13)
Rectal Salicylates	0.85	(0.51–1.43)	0.75	(0.37–1.49)

*Estimates from multi-variable logistic regression models adjusted for all other factors simultaneously

†OR = Odds Ratio

‡95% CI = 95% Confidence Interval

§ED = Emergency Department

#Includes Azathioprine, 6-Mercaptopurine, and Methotrexate

**Includes Infliximab and Adalimumab